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A CHALLENGE TO EARTHQUAKE RESEARCH

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In the history of earthquake studies there are certain red-letter dates that have special significance either because of the occurrence of a particularly noteworthy earthquake, the recording of special earthquake data, or because of the discovery of a far-reaching and seminal concept. To these red-letter dates there must now be added 1977, the year that earthquake studies received the official attention and approval of the United States Congress; the year that saw the passage by Congress of the Earthquake Hazards Reduction Act. This Act, I believe, can be attributed to the shock effects of the 9 February 1971, San Fernando, California earthquake, and, particularly to the lasting concern of Senator Alan Cranston when he viewed the resulting damage. In the past, strong public shock was generated by such events as the 1906 San Francisco earthquake, the 10 March 1933 Long Beach earthquake, and the 27 March 1964 Alaska earthquake. The death and destruction caused by these made strong impressions on the public, but not for long. The shock effect of these events tended to die away quickly and support for increased research to solve earthquake problems was not generated. The passage of the Earthquake Hazards Reduction Act six years after the San Fernando earthquake, demonstrates an aspect of the more informed and longer-lasting interest in the earthquake problem on the part of Congress, State legislatures, and local government agencies.

The Earthquake Hazards Reduction Act focuses on seismology and earthquake engineering, and the Act states clearly that solutions of the most important earthquake problems are expected as a result of the research funding provided. By means of this Act Congress, in effect, is directing government agencies, in particular the U.S. Geological Survey and the National Science Foundation, to solve the earthquake problem. In a broader sense, Congress and the public expect seismologists-geologists and earthquake engineers to solve the main problems posed by the occurrence of earthquakes. If the expected solutions do not develop over a reasonable period of time, it will almost certainly reflect adversely on those who do such research.

Because of its importance, the Earthquake Hazards Reduction Act makes a worthy subject for this year's presidential address. Certainly we should all be familiar with the significant parts of the Act so that we know its objectives and its specific elements. The preamble of the Act states that a large portion of the population of the United States lives in areas vulnerable to earthquakes and that earthquakes have caused, and can cause in the future, enormous loss of life, injury, destruction of property, and economic and social disruption. It goes on to state that "an expertly staffed and adequately financed earthquake hazards reduction program, based on federal research and contributions, and State, local and private participation, would reduce the risk of such loss, destruction, and disruption in seismic areas by an amount far greater than the cost of the programs. A well-funded seismological research program in earthquake prediction could provide data ade-

quate for the design of an operational system that could predict accurately the time, place, magnitude and physical effects of earthquakes in selected areas of the United States. An operational earthquake prediction system can produce significant social, economic, legal and political consequences."

In describing the National Earthquake Hazards Reduction Program, the Act states that "the President shall establish and maintain, in accordance with the provisions and policy of this Act, a coordinated earthquake hazard reduction program which shall be designed to achieve the objectives set forth; involve, where appropriate, each of the agencies listed; and include each of the elements described." The Program includes relevant seismological-geological research, earthquake engineering research, and research on disaster mitigation, and the Act states that the objectives of the Program shall include each of the following:

1. "The implementation, in all areas of high or moderate seismic risk, of a system (including personnel, technology, and procedures) for predicting damaging earthquakes and for identifying, evaluating, and accurately characterizing seismic hazards.

2. The development of technologically and economically feasible design and construction methods and procedures to make new and existing structures, in areas of seismic risk, earthquake resistant.

3. The development, publication, and promotion, in conjunction with State and local officials and professional organizations, of model codes and other means to coordinate information about seismic risk with land-use policy decisions and building activity.

4. The development, in areas of seismic risk, of improved understanding of, and capability with respect to, earthquake-related issues, including risk control, pre-event planning, warning dissemination, emergency services, reconstruction, and redevelopment.

5. The education of the public, including State and local officials as to earthquake phenomena, the identification of locations and structures which are especially susceptible to earthquake damage, ways to reduce the adverse consequences of an earthquake, and related matters.

6. The development of research on: (a) ways to increase the use of existing scientific and engineering knowledge to mitigate earthquake hazards; (b) the social, economic, legal, and political consequences of earthquake prediction; and (c) ways to assure the availability of earthquake insurance or some functional substitute.

7. Basic and applied research leading to a better understanding of the control or alteration of seismic phenomena."

The Act proceeds to describe research that should be done and which agencies may be involved. The Act states that the Program shall include each of the following elements:

(1) "research into the basic causes and mechanisms of earthquakes;

(2) development of methods to predict the time, place, and magnitude of future earthquakes;

(3) development of an understanding of the circumstances in which earthquakes might be artificially induced by the injection of fluids in deep wells, by the impoundment of reservoirs, or by other means;

(4) evaluation of methods that may lead to the development of a capability to modify or control earthquakes in certain regions;

(5) development of information and guidelines for zoning land in light of seismic risk in all parts of the United States and preparation of seismic risk analyses

useful for emergency planning and community preparedness;

(6) development of techniques for the delineation and evaluation of the political effects of earthquakes, and their application on a regional basis;

(7) development of methods for planning, design, construction, rehabilitation, and utilization of manmade works so as to effectively resist the hazards imposed by earthquakes;

(8) exploration of possible social and economic adjustments that could be made to reduce earthquake vulnerability and to exploit effectively existing and developing earthquake mitigation techniques;

(9) studies of foreign experience with all aspects of earthquakes."

The Act states that in assigning the role and responsibility of Federal departments and agencies, the President shall, where appropriate, include the United States Geological Survey, the National Science Foundation, the Department of Defense, the Department of Housing and Urban Development, the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, the National Bureau of Standards, the Energy Research and Development Administration, the Nuclear Regulatory Commission, and the National Fire Prevention and Control Administration.

The Act requires the President to develop through a designated Federal agency an implementation plan which shall set year-by-year targets through at least 1980, and shall specify the roles for Federal agencies, and recommend appropriate roles for State and local units of government, individuals, and private organizations, in carrying out the implementation plan. "The plan shall provide for:

(a) the development of measures to be taken with respect to preparing for earthquakes, evaluation of prediction techniques and actual prediction of earthquakes, warning the residents of an area that an earthquake may occur, and ensuring that a comprehensive response is made to the occurrence of an earthquake;

(b) the development of ways for State, county, local, and regional government units to use existing and developing knowledge about the regional and local variations of seismic risk in making their land use decisions;

(c) the development and promulgation of specifications, building standards, design criteria, and construction practices to achieve appropriate earthquake resistance for new and existing structures;

(d) an examination of alternative provisions and requirements for reducing earthquake hazards through Federal and federally financed construction loans, loan guarantees, and licenses;

(e) the determination of the appropriate role for insurance, loan programs, and public and private relief efforts in moderating the impact of earthquakes;

(f) dissemination on a timely basis of: instrument derived data of interest to other researchers; design and analysis data and procedures of interest to the design professions and to the construction industry; and other information and knowledge of interest to the public to reduce vulnerability to earthquake hazard."

The Act states that the President shall provide an opportunity for participation by the appropriate representatives of State and local governments, and by the public, including representatives of business and industry, the design professions, and the research community, in the formulation and implementation of the program. Such non-Federal participation shall include periodic review of the program plan,

considered in its entirety, by an assembled and adequately staffed group of such representatives. Measures developed for the evaluation of prediction techniques and actual prediction of earthquakes shall provide for adequate non-Federal participation. The President shall, within ninety days after the end of each fiscal year, submit an annual report to the appropriate authorizing committees in Congress describing the status of the program, and describing and evaluating progress achieved in reducing the risks of earthquake hazards.

It is certainly unusual for the government to make such explicit demands of a research field. It is true that a somewhat similar situation occurred in the health field when Congress, in effect, directed medical and biological research to find a cure for cancer. But in this case the demands were not made upon such a narrow field of research and upon such a small body of research workers. Those doing research related to earthquakes and their effects must now prepare to meet the challenge of the Earthquake Hazards Reduction Act. Our statements in the past have indicated that research can solve the earthquake prediction problem, that research can develop better ways to build safe and economical structures, and that research can mitigate earthquake disasters; and the appearance of such statements in National Research Council reports, in journals, and in newspapers have no doubt come to the attention of Congressmen and influenced them to vote for the Earthquake Hazards Reduction Act. We must now try to ensure that our research will be productive of the desired results even if it is uphill work, and that it does not follow non-relevant avenues which may offer enticing vistas and paths of least resistance.

The precedent for giving presidential addresses was established by George Washington, and in his address he warned against foreign entanglements and other things that might be detrimental, in his opinion, to the well-being of the country. Emulating Washington, I should like to warn against practices that might be detrimental to our research programs. I warn against: (1) becoming involved in foreign entanglements, if they lead to prolonged pursuit of unproductive lines of research; (2) trying to climb the mountain just because it is there, for the productive approach may lie in a different, non-obvious direction; (3) becoming the feeders of the computers just because they have voracious appetites for consuming and digesting data and prodigious capabilities for generating reports; (4) being misled into believing that statistical analyses unimaginatively employed will necessarily generate new and useful data; for example, although statistical analysis tells us that the "average American" has one-half male characteristics and one-half female characteristics, such information will not be useful in decision making, in most cases; (5) giving names to poorly defined or ambiguous concepts and then using the names to carry out precise logical analyses and drawing conclusions from the results; (6) being misled by the fallacy of simplification; that is, deliberately simplifying a problem until it is easily solved and then believing that the simplified solution must necessarily be informative about the unsimplified problem; (7) developing the screwdriver syndrome; that is, having possessed ourselves of a new screwdriver we should not go about trying to tighten all the screws we can find; (8) accepting the fallacy of the ritual; just because valuable benefits were once obtained by means of a certain procedure, it does not follow that turning the procedure into a ritual will ensure future benefits.

If we avoid unproductive approaches, there is no doubt that our research can produce valuable results. In fact, the development in seismology and earthquake engineering in recent years is evidence that similar development can be achieved in

the future by innovative thinking. The challenge provided by the Earthquake Hazards Reduction Act is of such importance that it should be born in mind, and I propose that the following Presidents of the Seismological Society, in their annual addresses, report on progress being made in meeting the challenge posed by the Act.

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